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DIGITAL TWIN OF AUTONOMOUS UNDERWATER VEHICLE ASSISTED BY AUTONOMOUS SURFACE VEHICLE

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ABSTRACT

Autonomous Under Water Vehicle (AUV) is major research vehicle in oceanography and for military purposes. These vehicles are more capital intensive to build and once deployed in the ocean, it loses all the connectivity to the terrestrial world and hard to predict the working status and the health of the AUV which not only hinders the transparency of the AUV but also eclipse the real time data extraction capabilities. This paper specifically addresses this issue by deploying the Autonomous Surface Vehicle (ASV) which moves in synchronous with the AUV and is acoustically connected to AUV under the water. The extracted health and surveillance data thus be visualized through the integration of IoT Twin maker service, a digital twin technology service provided by Amazon Web Services (AWS). Besides, the ability to process data locally and take on spot decisions can be attained by plugging GreenGrass IoT, an Edge computing software provided by AWS. The results depict the digital twin model of an AUV along with its real time health status.

Keywords: Iot, Edge Computing, Amazon Green Grass Iot, Amazon Iot Sitewise, Lambda Functions, Raspberry-Pi, Raspberry-Pi Camera, Digital Twin Maker Using Grafana

I. INTRODUCTION

An autonomous underwater vehicle (AUV) is an uncrewed, untethered, underwater vehicle capable of self-propulsion without the intervention of human-beings. With advancements in AUV research, materials, manufacturing techniques, sensors, computational capacity, and battery technology, autonomous underwater robots capable of making decisions have become more dependable and applicable [1]. A large number of AUVs have been developed, ranging in dry weights from less than 50 kg to nearly 9000 kg, with the majority of vehicles at the small end of the scale. With the development of intelligent devices and Internet of Things (IoT) technology, people are committed to constructing a smart ocean system [2] and Internet of Underwater Things (IoUT) [3]. These self-driven vehicles lose connectivity to the terrestrial world as soon as they enter into the water for operations. To make it visible digitally, we have incorporated the technology known as Digital Twin[5] where the real time functionalities can be monitored at ease. To establish the connectivity, the Autonomous Surface Vehicle (ASV) will be put on the surface of the water which is connected to AUV through the acoustic transceivers and converts the acoustic signals into radio waves and transmits them to the shore through radio link. Through user, the obtained data is then sent to the AWS cloud through which the data can be visualized with the aid of IoT Twinmaker [5] of AWS.

II. METHODOLOGY

We utilized Amazon Web Services (AWS), which offers advanced tools capable of creating digital replicas or mirror images of various entities. Amazon Web Services (AWS) offers a suite of services that can be effectively utilized for Autonomous Underwater Vehicles (AUVs), Autonomous Surface Vehicles (ASVs), and their corresponding digital twin technologies

Greengrass IoT includes two primary devices such as

1. Greengrass Core that operates on Linux, including Ubuntu and Raspbian, and supports Arm or x86 architectures.
2. Greengrass-aware devices that support Amazon FreeRTOS SDK for tiny microcontrollers and larger microprocessors. In this paper, Greengrass core can be taken as a central device in which it is hosted by the

Raspberry-Pi at the shore. Another Raspberry-pi processor inside the AUV is connected to the on-board sensors like accelerometer, gyroscope, voltage & current sensors etc., can fetch the health parameters about the AUV and make the data in the structured format.

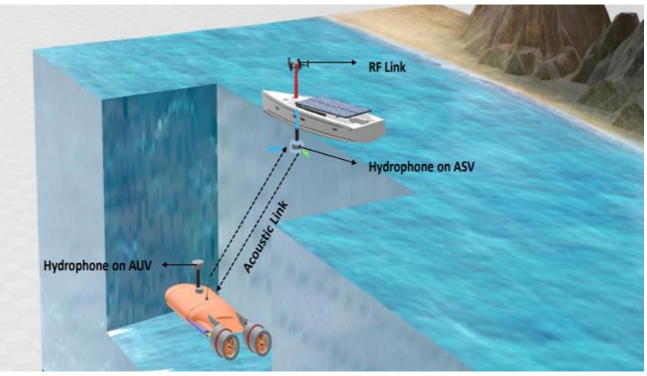

Fig 1: Schematic of AUV-ASV connection

This data is transmitted through the acoustic transducer to the ASV sitting on the surface of the water as shown in fig 1. The ASV will then sends the information to the Greengrass core[4] hosted raspberry-pi on the shore through the radio link and syncs the data to the AWS IoTSitewise and IoT Twinmaker[5] through Greengrass IoT Gateway.

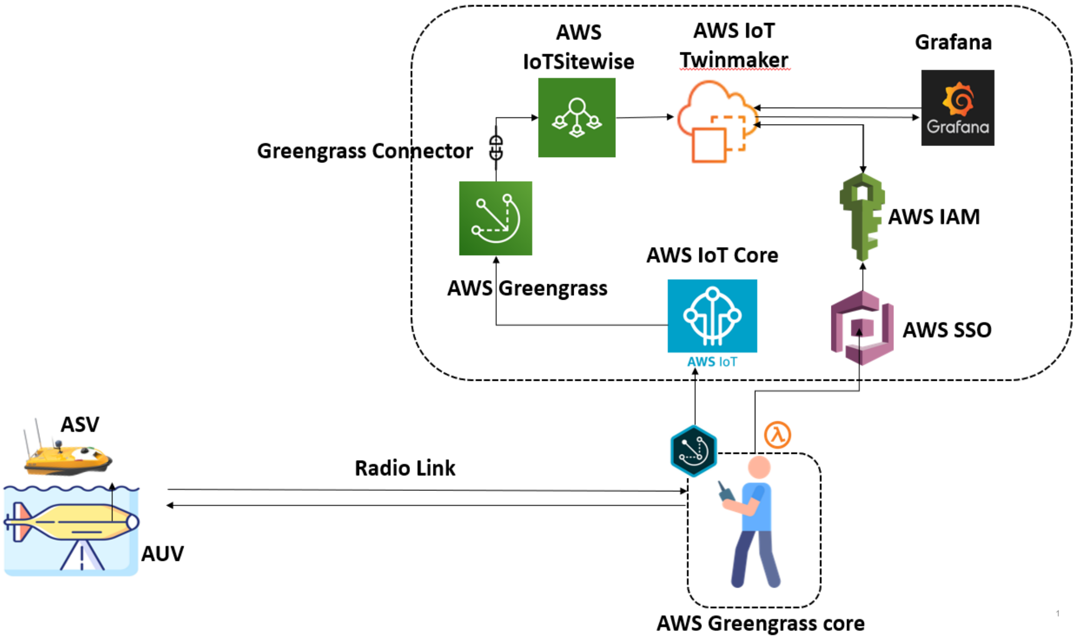

Fig 2: Overall architecture of the proposed solution detailing the services used along with the workflow schematic

From Greengrass IoT [4] connector, the AWS Digital twin maker is connected and the structural model is displayed with the aid of Grafana with all the parameters obtained from the AUV as depicted clearly in the overall architectural schematics in fig 2. AWS IoT TwinMaker provides the tools you need to build digital twins to help you optimize building operations, increase production output, and improve equipment performance. With the ability to use existing data from multiple sources, create virtual representations of any physical environment, and combine existing 3D models with real-world data, you can now harness digital twins to create a holistic view of your operations faster and with less effort (figure 2).

This paper reports the implementation of the digital twin of the AUV by incorporating various sensors like temperature, voltage, current, Accelerometers and Gyroscopes etc., which reports the health status of an AUV. For data extraction, the AUV has an on-board turbidity sensor that can monitor the turbidity levels of the water and also can be visualized in the twinmaker dashboards

Amidst these coordinated efforts, the Twinmaker digital system orchestrates the entire operation. By generating a virtual replica of both the AUV and ASV, the Twinmaker offers a comprehensive visualization of their activities. This digital twin not only monitors the current operations but also analyzes historical data, identifies patterns, and predicts potential challenges We utilize Amazon Web Services (AWS), which offers advanced tools capable of creating digital replicas or mirror images of various entities. Amazon Web Services (AWS) offers a suite of services that can be effectively utilized for Autonomous Underwater Vehicles (AUVs), Autonomous Surface Vehicles (ASVs), and their corresponding digital twin technologies

III. MODELING AND ANALYSIS

Demonstrating the hardware of an Autonomous Underwater Vehicle (AUV) can be challenging due to its underwater nature. the components and explain their functions as shown in fig 3.

1. **Frame and Body -**The overall structure of the AUV is constructed using the PVC pipe in a cylindrical format and closed at the edges. Divided as Internal chamber and External Chamber. Where the Internal Chamber consist of different Sensors and a microcontroller Board. And the External chamber consist of Screwing Mechanism for the deployment process. The ratio of this AUV is of 8cm*4cm with length and diameter of the AUV.
2. **Propulsion System-**The propulsion system of an Autonomous Underwater Vehicle (AUV) typically consists of thrusters or propellers that generate thrust for movement. These systems can be electric, hydraulic, or pump-jet based, providing efficient propulsion in various directions. Controlled by the onboard computer, the propulsion system integrates with the navigation system for precise maneuvering and obstacle avoidance. Some AUVs feature redundant propulsion systems for enhanced reliability. Overall, the propulsion system is essential for the AUV's autonomy and performance in underwater environments.
3. **Deployment-** The AUV deployment mechanism utilizes a screw mechanism to sink into the water by injecting water at the edges. Once submerged, it pumps out the water to create buoyancy, allowing it to float on the surface. This mechanism enables controlled submersion and resurfacing of the AUV for efficient deployment and retrieval.
4. **Power Source-** Lithium-ion batteries are used for powering Autonomous Underwater Vehicles (AUVs) due to their high energy density, lightweight, and rechargeable nature. These batteries provide the necessary power for the AUV's propulsion system, onboard electronics, and sensors, allowing for extended mission durations. Proper management and monitoring of lithium-ion batteries are essential to ensure safe and efficient operation of the AUV.
5. **Sensors-** Sensors play a critical role in the functionality of an Autonomous Underwater Vehicle (AUV), providing essential data for navigation, environmental monitoring, and mission-specific tasks. These sensors are typically placed strategically throughout the AUV's structure, including its hull and internal compartments, to gather data on parameters such as depth, temperature, pressure, and water quality. The data collected by these sensors are processed and analyzed by an onboard Arduino microcontroller, which acts as the central hub for data collection and control. The Arduino processes sensor data in real-time, enabling the AUV to make autonomous decisions based on its surroundings. This integration of sensors and Arduino enhances the AUV's ability to navigate underwater environments, collect scientific data, and perform complex tasks with precision and efficiency. Here are the following Sensors that we have used,

- **Temperature and Humidity Sensor** measures ambient temperature and humidity levels, provides data for environmental monitoring and control and helps in assessing the AUV's operating conditions. **5.2 Voltage Sensor** monitors the voltage levels of the AUV's power supply, ensures the battery is operating within safe limit and helps in managing power consumption and optimizing battery life
- **Vibration Sensor** detects vibrations in the AUV's structure or environment, used for detecting impacts or abnormal conditions and helps in ensuring the structural integrity of the AUV.
- **Accelerometer and Gyroscope** measures acceleration forces, including gravity, gyroscope measures orientation and angular velocity and used for navigation, attitude control, and motion tracking. **5.5 Current Sensor** monitors the current flowing through electrical components, helps in managing power distribution and detecting faults and ensures efficient operation and prevents overloading.

- **Turbidity Sensor** is used to measure the cloudiness or haziness of a fluid caused by suspended particles. It works by emitting light into the fluid and measuring the amount of light that is scattered or absorbed by the particles, providing an indication of water quality or sediment concentration

6. **Communication System-** As of now we are using a tethered communication for the under water vehicle to the surface vehicle for communication establishment.
7. **Processing Unit-** The ASV is directly connected to the Shore using AWS Cloud and the digital twinning of the ASV to the shore along with graphana allows the user to visualize the live data.
8. **Simulation or Video:**

Demonstration- : https://youtu.be/slpJtubOPKQ?si=xzR9hEw47AngOt9j
Functioning- : https://youtube.com/shorts/mJosKiw4TcI?si=WCXA4tRWhk6jq7Uk

Fig 3: Functioning AUV with ASV

IV. RESULTS AND DISCUSSION

The results achieved provide a comprehensive digital twin model for AUVs, offering invaluable insights into their real-time health and status, thereby enhancing their transparency and data extraction capabilities. Leveraging AWS services, a dynamic dashboard as shown in fig 4. has been constructed, which efficiently collects and displays real-time data such as temperature, humidity, and motion of the AUV. In the hardware domain, we've designed the AUV with buoyancy control and connected it to the ASV, which collects data from the AUV and transmits it to shore using Greengrass core[4] software. This innovation has tremendous potential to enhance the efficiency and reliability of AUV deployments in oceanography and military applications.

The Figure (4) showcases the data obtained from a diverse set of sensors, each specialized in monitoring distinct physical parameters. Among these sensors are temperature sensors, responsible for tracking ambient temperatures, turbidity sensors, which assess the clarity of fluids, and humidity sensors, designed to measure moisture levels in the air. Additionally, voltage sensors monitor electrical potential differences, while current sensors track the flow of electric charge in circuits. Each sensor operates by converting its specific physical input into electrical signals, which are then processed and recorded for analysis This data is crucial for understanding environmental conditions, evaluating system performance, and ensuring operational efficiency.

Fig 4: Represenatation of digital twin on the dash board using AWS Grapahana.

The insights gleaned from these sensors enable proactive maintenance, efficient resource management, and informed decision-making in a variety of applications, from industrial processes to environmental monitoring. The data from all sensors can be represented as a table or list, with each row corresponding to a reading from all sensors at a particular timestamp (Figure 5).

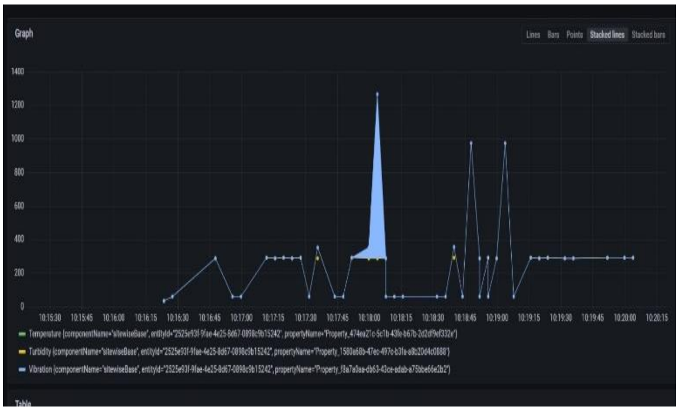

Fig 5: Representation of Sensor data in a graphical format

V. CONCLUSION

This paper describes an innovative solution for addressing the challenge of monitoring and maintaining Autonomous Underwater Vehicles (AUVs) in remote ocean environments. By deploying an Autonomous Surface Vehicle (ASV) that communicates acoustically with the AUV, real-time health and surveillance data can be extracted and visualized using Amazon Web Services' IoT Twin maker service. Additionally, on-thespot decision-making capabilities are enhanced through AWS GreenGrass IoT, enabling a comprehensive digital twin model for AUVs and ensuring transparency and real-time data extraction, thus advancing the field of oceanography and military applications.

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